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How do energy & environmental policy goals and instruments affect electricity demand? A framework for the analysis

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Abstract

Several measures in the environment and energy realms are currently being implemented in the EU and its Member States. Three of these instruments, with an impact on the electricity market, are demand side management activities, promotion of electricity from renewable energy sources and measures aimed at the mitigation of Greenhouse Gas (GHG) emissions. The objective of this paper is to analyse the impact of these energy efficiency and environmental goals and instruments on electricity demand and costs to electricity consumers when electricity markets are either national or international and when those policies are implemented by a national or an international institution. The paper shows that the effectiveness and impact of those measures largely depends on the demand response in the electricity market. An additional conclusion is that, when either the electricity markets or the support policies are national, distortions may occur, i.e. the reductions in electricity demand in one country may be subsidised by consumers or taxpayers in another country.

Keywords: Electricity demand; Dsm; Climate policy; Renewable energy policy

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Contents

1. Introduction 2007
2. Scope, methodology and basic assumptions 2007
3. How do energy and environmental goals and instruments affect electricity demand response? 2009
   3.1. Energy efficiency measures and dsm: impact on electricity demand 2009
      3.1.1. Reduction of non-service electricity demand in households 2009
      3.1.2. Effects of energy efficiency policies 2014
   3.2. Impact of RES-E deployment on electricity demand and consumer costs. 2018
   3.3. Impact of CO_2 quotas and emission trading schemes (ETS) on electricity demand and consumer costs. 2024
4. Limitations of the study and suggestions for further research 2030
5. Concluding remarks. 2031
   References 2031

1. Introduction

The environment and energy realms have traditionally been two major focus of attention of EU and Member State (MS) policy. This attention has intensified in recent years as a response to, both, internal and external events and strategies (i.e., the Kyoto Protocol).

In this context, the EU and its MS have implemented ambitious environmental and energy goals and measures, having an impact on the electricity market. Demand Side Management (DSM) activities, promotion of electricity from renewable energy sources (RES-E) and measures aimed at the mitigation of Greenhouse Gas (GHG) emissions are arguably three of these instruments. These policies interact. Although there might be conflicts between them, there are also mutually reinforcing effects with significant policy implications. Actually, as stated in the Amsterdam Treaty, environmental protection is one of the major goals of energy policy. In turn, the energy sector is instrumental in the success of environmental policy.

The effectiveness and impact of these measures depend to a large extent on the demand response in the electricity market. The objective of this paper is to analyse the impact of these energy efficiency and environmental goals and instruments on electricity demand and costs to electricity consumers when electricity markets are either national or international and when those policies are implemented by a national or an international institution. This paper provides a theoretical framework for the analysis of the interactions between electricity demand response and the above mentioned energy-environment measures.

Accordingly, the paper is organised as follows. The next section describes the methodology and main assumptions. Section 3 analyses the main effects of energy and environmental goals on electricity demand under a variety of cases and scenarios. The main limitations of the study are considered in Section 4. The paper closes with a concluding section.

2. Scope, methodology and basic assumptions

With the help of a graphical method, the impacts of policies will be analysed against a baseline (a reference scenario) using a comparative static analysis. Energy efficiency (EE)

measures, RES-E deployment and CO2 quotas and trading affect electricity demand differently. Variations in the total costs for the consumer will be considered.

Two types of effects on electricity demand are envisaged. So called "direct effects" (shifts in the demand curve) and "indirect effects" (shifts in the electricity supply curve which, through the interaction with the demand curve, affect the price of electricity and the quantity of electricity demanded).[1]

Given the gradual transition to an integrated European electricity market and, also, the competency of the EU institutions concerning energy and environmental policies, we consider four scenarios:

(1) National electricity market and national environmental-energy policy.
(2) National electricity market and international environmental-energy policy.
(3) International electricity market and national environmental-energy policy.
(4) International electricity market and international environmental-energy policy.

The main assumptions of this paper are:

- Concerning the supply curve, we assume the typical increasing form (with a constant slope).
- Concerning demand, we assume a basic scenario of highly inelastic electricity demand to price variations.
- A perfect competition framework (marginal cost pricing) is assumed.
- Three "energy and environment" goals are analysed: DSM, promotion of RES-E and CO2 quotas TEAs and only the directions of effects will be considered.
- In the case of DSM, energy efficiency and RES-E policy, consumers are affected by the reduction in the electricity price as a result of the policy and by the costs of the policies themselves. The latter effect tends to counteract the reduction in electricity demand caused by the reduction in price. In the case of CO2 quotas, the result is an increase in electricity prices.
- Income effects, which could increase electricity consumption, are disregarded. The increase in consumer disposable income as a result of the reduction in the consumption of (non-service) electricity demand would not be spent on electricity consumption. Therefore, only price effects are considered, because electricity expenses represent a small share in the total budget (expenditures) of households. Considering these effects would further complicate the analysis.
- The variations of the costs faced by the generators (either an increase or a reduction) are passed to the final consumer.
- We will not analyse the interactions between the instruments because it would greatly complicate the analysis and it is beyond the aim of this paper.[2]

In Section 4 the implications of the above mentioned assumptions are discussed.

[1] Changes in the elasticity of the electricity demand curve are not analysed deeply, although the authors strongly believe this could be a fertile ground for future research.

[2] For the interactions between RES-E promotion and GHG mitigation, see [1–3]. For other interactions, see [4].

3. How do energy and environmental goals and instruments affect electricity demand response?

3.1. Energy efficiency measures and dsm: impact on electricity demand

In this case, a distinction between DSM measures which reduce "non-service demand" in households and those which improve energy efficiency is deemed necessary.

3.1.1. Reduction of non-service electricity demand in households

Concerning electricity demand by households, a distinction between two types of final demand is relevant. One is the electricity demand which covers needs and wants (basic and superfluous). In other words, the consumer effectively uses electricity for his own satisfaction. We call this "service" demand. However, most consumers of electricity also use electricity everyday without receiving a service in return. They do so when, for example, they turn on the lights of a house without using some of them. In this case, the consumer is paying for electricity he is not really profiting from. We call this "non-service" electricity demand. Some information campaigns aim at reducing this non-service demand. Total demand is the sum of service and non-service demand.[3]

**Scenario 1. National electricity market and national support policy:* The share of this non-service demand on total demand is difficult to know, but it can be expected to be small (10–15%). Therefore, information campaigns would lead to the reduction in non-service demand (NSD) and, thus, to a small reduction in total demand (TD) (see Figs. 1 and 2).

As a result of the DSM policy, the electricity demand would be reduced and, ceteris paribus, the price at the spot market would go down. This would shift the service-demand curve to the right of SD_0 (and, thus, total demand to the right of TD') although probably not to the right of TD_0.[4] The later would be the case if the cost of information campaigns was paid through the general budget (raising taxes). However, if these costs were passed to the consumer through its electricity bill, then the position of the final demand curve would depend on the total net costs for the consumer. If the reduction in the power price was above the increase in the costs of support passed to the consumer, then the final curve (TD_1) would be between TD_0 and TD'. If it was below, the final demand curve would be to the right of TD_0, but this is unlikely.

Consumers reducing their total demand (as a result of the information campaigns) would benefit twice, due to the lower payments (reduction in NSD) and to the reduction in the price of electricity for their service demand (SD). These consumers would have to pay for the policy. In contrast, for consumers whose NSD does not respond to the information campaigns, they only benefit from a reduction in the electricity price, while they will still have to pay for the policy. In the first case, a displacement of the electricity demand curve to the left could be expected, whereas this would not occur in the case of non-responsive consumers. Only aggregate effects are analysed here, however (Table 1).

**Scenario 2. International electricity market and national support policy*: Let us assume that there are two countries: country A implements a DSM policy to reduce NSD, whereas

[3]In the following figures we assume that the elasticity of NSD and SD is the same. However it could be expected that the NSD curve would be less responsive to price changes than the SD curve (i.e., more inelastic).

[4]Remember than in this and the following sections we disregard the impact of income effects on electricity demand (i.e., after the reduction in electricity prices, the consumer would have more income to spend, leading to an increase in electricity consumption).

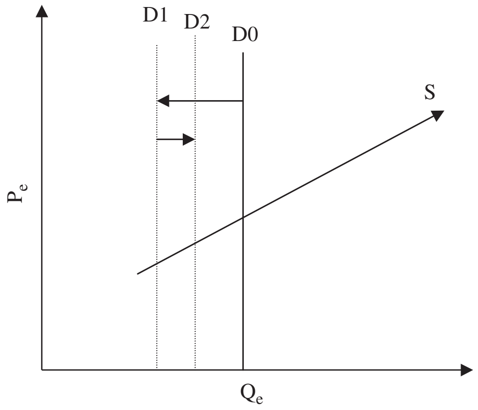

Fig. 1. Energy efficiency and DSM: Impact on electricity demand (case 1, inelastic demand).

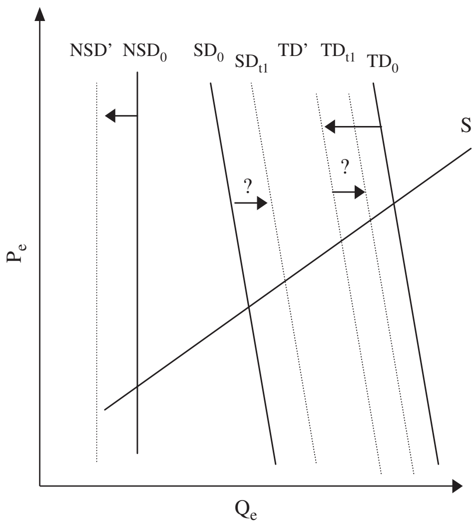

Fig. 2. Country A.

Table 1
Summary of effects (sc. 1)

Electricity demand	↓
Price of electricity	↓
Consumer costs (responsive consumers)	↓
Consumer costs (non-responsive consumers)	↓ (depends on policy costs pass-through)
Impact on other countries	Negligible

country B does not. In this case, NSD would go down in country A. If the policy to reduce NSD is effective in country A and this is a large country, the policy would reduce total international demand. Since the interaction of international demand with international

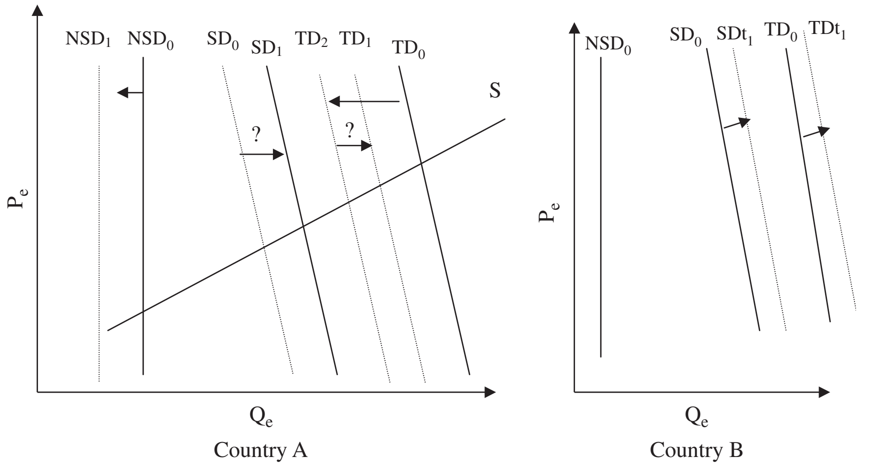

Fig. 3. Country A large.

supply determines the international electricity price, this would go down (Fig. 3), which would benefit consumers in both countries. Consumers in country A would reduce their NSD and they would have to pay for the policy. Consumers in country B would not reduce their NSD but they would not pay for the policy (they would "free-ride" on the policy efforts of country.

If A was small, those consumers reducing their NSD would reduce their costs of electricity provision. However, the electricity price would not go down but all consumers in A would still have to pay for the policy through a charge on their electricity bill. Therefore, SD would be reduced and would shift to the left of SD_0. Consumers in B would remain unaffected (Fig. 4).

To sum up, the final electricity demand in the country would not change from the initial position but its consumers would still have to pay for the policy. This means that, on aggregate, consumers' welfare would remain unchanged compared to the *ex-ante* situation but they would be worse off than in scenario 1 (when they benefited from a lower spot power price) (Table 2).

**Scenario 3. National electricity market and international support policy*: In this case, we assume that the policy would be promoted by an international institution and that its cost would fall on all electricity consumers according to their electricity demand.

However, this policy could have a different impact in countries where the effectiveness of the policy is also different.[5] For example, let's assume that in A the policy is effective and it is ineffective in B.

Fig. 5 shows that, in country A, a reduction of NSD and TD would occur. In country B a reduction of TD would occur not because NSD goes down but because the country has to pay for the policy without benefiting from it (no reduction in electricity price). This reduction in B could be larger than the reduction of demand in A, although this depends on the extent to which the reduction in the electricity price in A is compensated by the

[5]Note that, contrary to scenario 3, it is not interesting to consider the size of the countries, because electricity markets are national and, therefore, not linked through an "international electricity price".

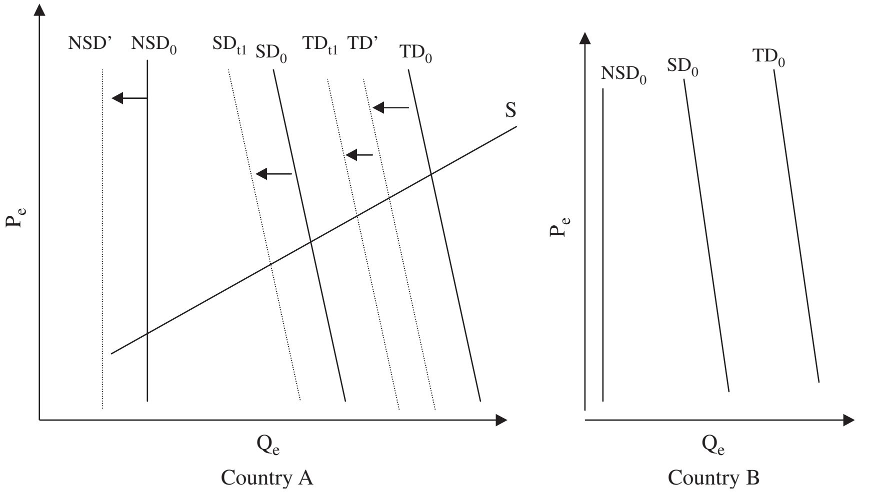

Fig. 4. Country A small.

Table 2
Summary of effects (sc. 2)

Electricity demand	A large: ↓ in A; ↑ in B A small: ↓ in A; = in B
Electricity price	= (↓ if A is large)
Consumer costs	Ambiguous (↓ if savings from reduction in NSD are smaller than the increase in costs due to policy; ↑ if they are larger) A large: ↓ in A (lower NSD, lower electricity price, costs of policy); ↓ in B (lower electricity price) A small: ? for A (lower NSD but costs of policy; no change in electricity price); = in B (unaffected)

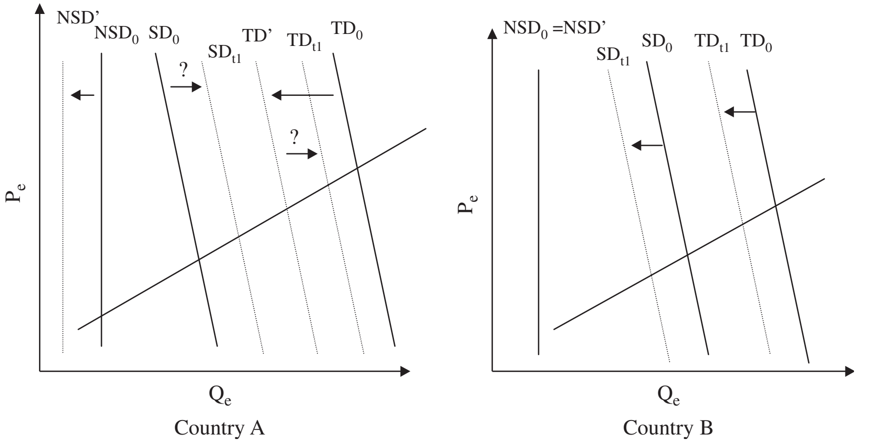

Fig. 5. Scenario 3. National electricity market and international support policy.

Table 3
Summary of effects (sc. 3)

Total electricity demand	↓ (reduction in both countries)
Electricity price	↓ in A ; = in B
Consumer costs	↓ in A; ↑ in B

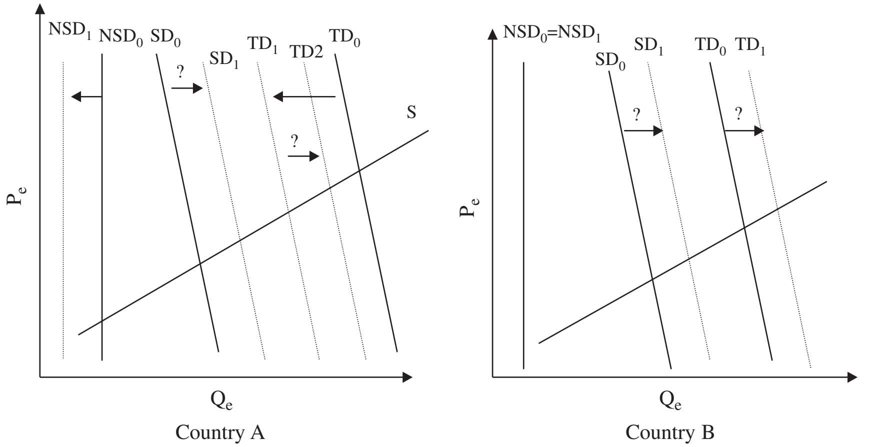

Fig. 6. Country A large.

increase of electricity costs for the consumer as a result of the policy. Consumers in A would benefit from this international policy (adding to the reduction in NSD the reduction in the electricity price), while consumers from B would not benefit, and they would still have to pay for it).

Therefore, if an international DSM policy is implemented in fragmented national electricity markets then, the less effective is the policy in one country, the more expensive is for the consumers in this country (Table 3).

Scenario 4. International electricity market and international support policy: Fig. 6 summarises the main effects in this scenario, which also assumes a different degree of effectiveness of the DSM policy in the two countries.

The reduction in demand in A would be larger than in B because the consumers of NSD in B are not responding to the DSM policy. However, as in scenario 2, we should consider the capability of countries to influence the electricity price. This depends on the total share of electricity demand of each country in international electricity demand, i.e., on how large is the country where the policy is effective (i.e., country A).

If A was large, then the international price of electricity would go down. If it was small, it would remain unchanged (Fig. 7).

If A is large, consumers benefit from the reduction in the international price of electricity, which tends to increase their demand (or to pay less for the electricity they buy). Therefore, some benefits of the international DSM policy remain in the country whose consumers respond to the policy. Other benefits are shared by the consumers in both countries (reduction in the electricity price) while the costs of the policy are also shared by all the consumers (Tables 4 and 5).

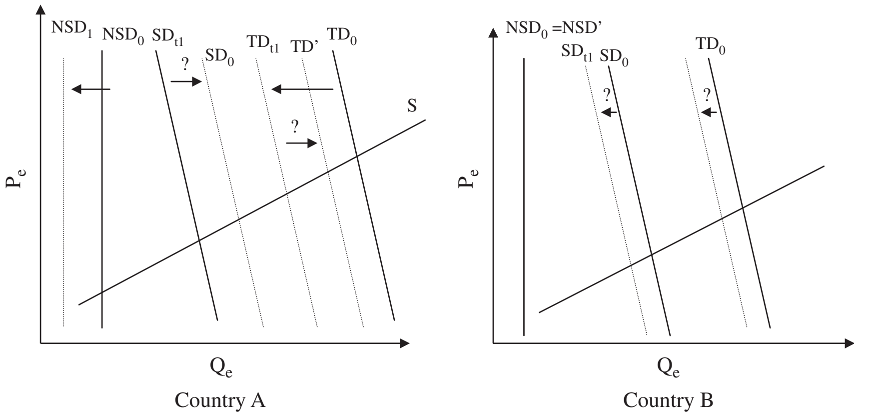

Fig. 7. Country A small.

3.1.2. *Effects of energy efficiency policies*

Information campaigns and subsidies on the adoption of energy efficient equipment and appliances by energy-intensive industrial companies could have on electricity demand and consumer costs. In many countries these policies are paid through the general budget. It would therefore not be realistic to assume that the costs of support would be passed directly to companies or to final electricity consumers. They would be paid by the taxpayers.

The policy would reduce electricity demand in adopting firms per unit of service (maintaining constant the service being provided).[6] Total demand would then decrease, and the electricity price at the spot market would go down. Adopting firms would benefit twice: lower electricity consumption and electricity price. But, interestingly, also other electricity consumers, which have not adopted energy-efficient technologies, would benefit from a lower electricity price. Lower electricity costs could be totally absorbed by firms, increasing their profits, or they might be passed to their products prices depending on several factors, including the structure of the products markets. For the country implementing this policy, a lower consumer price index (CPI), more competitiveness of its firms, lower imports and higher exports and better terms of trade would result.

**Scenario 1. National electricity market and national support policy*: This is basically the case referred above. The reduction in electricity price is likely to cause a small increase in demand afterwards (Table 6).

**Scenario 2. International electricity market and national support policy*: In this case, energy efficiency subsidies are provided by national authorities (through the public budget) but there is an international electricity market. Consumers and firms in countries not providing energy efficient subsidies (i.e., B) would also benefit (free-ride) on the policies of other countries, because the international electricity price would go down but they would not pay for the policy. Taxpayers in countries implementing the policy would be then supporting electricity demand reduction and would be subsidising the price reductions and

[6]Energy efficiency measures involves that the electricity needs are covered with less electricity demand. Individual and industrial consumers will see their basic and non-basic needs met as before the energy efficiency measures, but their electricity consumption will be reduced, because efficiency measures, by definition, involve a reduction of electricity consumption per unit of service.

Table 4
Summary of effects (sc. 4)

Total electricity demand	↓ (in both countries)(? in B if A is large)
Electricity price	= (↓ if A was large)
Consumer costs	If A is small: ↓ in A; ↑ in B If A is large: ↓ in A; ? in B

Table 5
Summary of effects (all scenarios)

	Electricity demand		Electricity price	Consumer costs	
	A	B		A	B
Scenario 1	↓	=	↓	↓	=
Scenario 2. A large.	↓	↑	=	↓	↓
Scenario 2. A large.	↓	=	↓	?	=
Scenario 3.	↓	↓	↓ in A = in B	↓	↑
Scenario 4. A large.	↓	?	↓	↓	?
Scenario 4. A small.	↓↓	↓	=	↓	↑

Table 6
Summary of effects (sc. 1)

Electricity demand	↓
Electricity price	↓
Costs to industrial electricity consumers (adopters)	↓↓
Costs to electricity consumers (non-adopters)	↓
Costs to taxpayers	↑
Costs to consumers of goods produced by adopters	↓
Macroeconomic effects for A:	
Lower CPI, better terms of trade, more competitive economy	

savings in the electricity bill of consumers in both countries. The impact of energy efficiency measures on the international price depends on the size of A. If A is large, then a reduction can be expected.

However, firms receiving support for EE measures would benefit twice (lower price and electricity consumption). The reduction in costs of electricity makes energy intensive firms in A more competitive in international markets because, even though producers in other countries would also benefit from lower electricity prices, their cost savings would be smaller compared to adopter firms in A. This tends to reduce the price of products of adopters in A, increasing its exports and reducing its imports leading to an improvement in the better terms of trade and in the current account balance. Recall that this is subsidised by taxpayers in A (Table 7).

Table 7
Summary of effects (sc. 2)

International electricity price	A large: ↓ A small: =
Electricity demand	↓ in A = in B (possible rebound effect if the international electricity price goes down)
Costs to industrial electricity consumers (adopters)	A large: −A: ↓↓ −B: ↓ A small: −A: ↓ −B: =
Costs to electricity consumers (non-adopters)	A large: −A: ↓ −B: ↓ A small: −A: = −B: =
Costs to taxpayers (A)	↑
Costs to taxpayers (B)	0
Costs to consumers of goods	↓

**Scenario 3. National electricity markets and international EE policy*: In this case, subsidies for EE would be provided by an international institution and paid through this institution's general budget (i.e., indirectly by taxpayers).

If we assume the policy was effective in stimulating EE measures in both countries, an important distinction is between adopters and consumers in countries providing funds and in countries net recipients of funds.[7] A lower electricity price and demand in both countries would result (Table 8).

Taxpayers in the net contributor country would subsidise the benefits of EE measures in both countries.

Alternatively, if the degree of effectiveness of the EE policy was different in both countries (policy being effective in A and ineffective in B), the price of electricity would go down in A and would remain constant in B. Costs to industrial electricity consumers in A would be reduced, because they would save costs (lower electricity consumption and price). Final electricity consumers in A would experience a smaller reduction in the costs of electricity provision (because they would benefit from the price reduction but not from a reduction in electricity consumption). Electricity consumers in B would be unaffected by the success of the policy in A.

Taxpayers in A would be subsidising the adoption of EE measures in their country, and consumers in this country would benefit from this (lower electricity demand and

[7]Note that, in contrast to scenario 2, it is not very interesting to consider the size of the countries, because electricity markets are national, with no interconnections. A change in electricity demand in one country would not affect the electricity price in other countries.

Table 8
Summary of effects (sc. 3)

	Country net provider	Country net recipient
Electricity demand	↓	↓
Electricity price	↓	↓
Costs to industrial electricity consumers (adopters)	↓↓	↓↓
Costs to electricity consumers (non-adopters)	↓	↓
Costs to consumers of goods produced by adopters	↓	↓
Costs to taxpayers	↑	0
CPI	↓	↓
Terms of trade	0	0

prices). In contrast, taxpayers would be promoting the reduction of electricity demand (and prices) in A. The later would not benefit from this (Table 9).

**Scenario 4. International electricity market and international support policy*—Two possible cases are considered:

(a) One country is large and the other is small and the policy is effective in both countries. There would be a reduction in electricity demand, electricity price and costs for consumers, financed by taxpayers in both countries. If both were small, then the international electricity price would not change. Consumers would not benefit but taxpayers would still pay for the policy. Only technology adopters in both countries would benefit.
(b) However, if the policy was ineffective in B but effective in A (large), the following effects would result.

(Table 10) Since A is large and capable of influencing the international electricity price, the success of the policy reduces this price. Consumers in both countries would benefit, whereas taxpayers in A and B would be subsidising this price reduction. The most benefited actors would be EE adopters in A. If they pass the cost savings to the price of their products, then the consumers of these products in A would benefit. These would make firms (adopters) in A more competitive in the international market. Paradoxically, taxpayers in B would subsidise the loss of competitiveness of their own country.

If the policy was ineffective in the large country (A) but effective in the small (B), a different picture would result (Table 11):

The implementation of EE measures in the small country would not affect the international electricity price (by assumption). Therefore, no consumer in A or B would benefit from a lower electricity price. The only beneficiary would be adopters in B. It would be especially detrimental for taxpayers in fund-providing countries if the international energy efficiency policy was ineffective in their own country, because then they would be subsidising the policy.

The following table summarises the impacts (Table 12).

Countries can use DSM and EE policies to reduce electricity demand. However, these policies do not lead to a reduction in electricity demand within the territory of the country but also to other effects in its country as well as in other countries (electricity prices and consumer costs). The intensity of these effects depends on several variables, including the

Table 9
Summary of effects (sc. 3)

Electricity demand	↓
Electricity prices	↓ in A; = in B
Costs to industrial electricity consumers (adopters)	↓↓ in A; = in B
Costs to electricity consumers (non-adopters)	↓ in A; = in B
Costs to consumers of goods produced by adopters	↓ in A; = in B (unless B substantially imports products from EE adopters in A)
Costs to taxpayers	↑ in both countries
CPI	↓ in A; = in B
Terms of trade	Improvement (A); worsening (B)

Table 10
Summary of effects (sc. 4)

Electricity demand	↓ in A; = in B
Electricity price	↓
Consumer costs (adopters)	↓↓ in A; ↓ in B
Consumer costs (non-adopters)	↓ in A; ↓ in B
Costs to taxpayers	↑ in A; ↑ in B
Costs to consumers of goods produced by adopters	↓ in A
Consumer price index (CPI): Small reduction in A	
Terms of trade: Improvement in A (less positive effect on B)	

Table 11
Summary of effects (sc. 4)

Electricity demand	↓ in B; = in A
Electricity price	=
Consumer costs (adopters)	= in A; ↓ in B
Consumer costs (non-adopters)	= in A and in B
Costs to taxpayers	↑ in A; ↑ in B
Costs to consumers of goods produced by adopters	↓ in B
Consumer price index (CPI): More or less unaffected in both countries	
Terms of trade: Small improvement in A	

national or international character of the international policies and electricity markets and the size of countries.

3.2. Impact of RES-E deployment on electricity demand and consumer costs

In contrast to DSM and EE measures, which directly impact the electricity demand curve, RES-E policy schemes affect the supply side of the electricity market, changing the price of electricity and the quantity of electricity demanded. The impact on electricity demand is indirect.

Table 12
Summary of effects (all scenarios)

	Electricity demand		Costs to electricity consumers				Costs to taxpayers		Elect. price
	A	B	Adopters		Non-adopters		A	B	
			A	B	A	B			
Scenario 1	↓	=	↓↓	=	↓	=	↑	=	↓(A); = (B)
Scenario 2a(I)	↓	=	↓↓	↓	↓	↓	↑	0	↓ in international price
Scenario 2b(II)	↓	=	↓	=	=	=	↑	0	= in international price
Scenario 3a(III)	↓	↓	↓↓	↓↓	↓	↓	↑	↑	↓
Scenario 3b(IV)	↓	=	↓↓	=	↓	=	↑	0	↓ price in A; = price in B
Scenario 4a(V)	↓	=	↓↓	↓	↑	↑	↑	↑	↓ internat. price
Scenario 4b(VI)	=	↓	=	↓	=	=	↑	↑	= internat. price

(I) A large; (II) A small; (III) Effective policy in both countries; (IV) ineffective policy in B, effective in A. (V) A large, policy effective in A, policy ineffective in B. (VI) A large, policy ineffective in A, effective in B.

Promotion of RES-E leads to the substitution of RES-E for conventional electricity. A reduction of the price at the spot power market results, because this is determined by the marginal conditions of the conventional electricity market [2]. However, since the reduction in the price of electricity is outweighed by the RES-E support costs, the final effect on consumers is ambiguous. The final effect on electricity demand is also ambiguous, because a reduction in the price of electricity triggers an electricity demand increase, but the higher consumer costs would reduce demand. It is difficult to say what the final impact will be.

Therefore, the share of RES-E in total electricity generation (and consumption) affects the conventional electricity price and, thus, triggers a demand response from electricity consumers.[8] However, this response will depend on several factors, one of the most important being the national or international character of the RES-E policy and the possibility of interconnections between national electricity markets. Therefore, four cases are investigated.

**Scenario 1. National electricity market and national RES-E support policy*: This is the current situation in the EU and the basic case mentioned above. RES-E policy is normally supported by consumers who pay the additional costs of RES-E deployment through their electricity bills.[9] The impact on costs for consumers and electricity demand in this basic scenario have already been analysed (see [4]), leading to the following final effects (Table 13):

Again, the reduction in the electricity price should be compared with the consumer cost increase due to the support. The final impact on total electricity demand is ambiguous and depends on the elasticity of the demand curve. Electricity demand remains constant by assumption. If a small elasticity was assumed, the analysis would be more complicated, but

[8]In reality, these two markets (electricity and TGC) are linked by the total electricity demand (assuming a relative quota): a total demand increase (reduction) leads to a more ambitious (less stringent) RES-E deployment ([4]).

[9]An exception are certain financial measures (exemptions, deductions etc...) and some investment subsidies, which are paid through the general budget, but these are normally secondary instruments (although for some technologies, notably the least mature ones, they represent very important support schemes).

Table 13
Summary of effects (sc. 1)

Electricity price	↓
Specific support costs (for consumers)	↑
Electricity demand	= by assumption (conventional electricity ↓ but RES-E ↑)
Total cost for consumers	Ambiguous[a]

[a]The final effect depending on the intensity of two contradictory forces (changes in electricity price and specific support costs for consumers). The authors suggest that the size of the two effects depends on the slope and level of the total electricity supply curve, the renewable energy supply curve and the size of the quota.

the results on electricity demand would also be ambiguous. However, if the costs of the support policy were not charged to the consumer but to the taxpayer, the electricity demand would be higher (lower electricity price).

**Scenario 2. National electricity market and international RES-E support policy*: We assume that an international support scheme is implemented, although electricity markets remain national and that the RES-E support scheme is a quota with TGC system. There are only two countries, a quota per country, a common TGC scheme and one uniform TGC price. However, since prices of electricity in national markets are different, the specific support provided to RES-E generators (difference between P_e and P_{TGC}) could also differ per country, although the total support would be the same ($P_e + P_{TGC}$)(Fig. 8).

Conventional electricity would be displaced and substituted by RES-E. The electricity price would go down in both countries, but probably relatively more in countries with a lower price (A). In these countries the additional support from a TGC scheme would be higher than in a country with a higher price of electricity (B) because TGC support (A) > TGC support (B) and total support—rice of electricity (A) > total support—price of electricity (B). Total electricity demand could be unaffected.

Ceteris paribus (i.e., similar ambitious targets), this would cause a relatively higher increase of RES-E deployment in A and, therefore, a reduction of conventional electricity. Since the spot market price is set by the conditions in the conventional electricity market and a greater reduction of conventional electricity in A has occurred, the electricity price in A would go down more than in B.[10]

The following table summarises the main effects (Table 14):

**Scenario 3. International electricity market and national RES-E support policy:* In this case, electricity trade between countries would be possible. Therefore, a unique international electricity price would result (P_e). But countries would retain the competency of their RES-E policy. If A had a more ambitious quota than B, the TGC price in A would be above that in B. Assuming reciprocity and mutual recognition of TGCs, this would create an incentive for producers in B to sell their RES-E production in A.

[10]A different question is if it would be interesting for a B generator to produce electricity in A. The answer is no, since the total support is the same in both countries (price of electricity lower but specific RES-E support higher). However, in comparison to country B, the incentive to produce RES-E in A would be higher than the incentive to produce RES-E in B. Although this incentive is higher, the total quota is fixed beforehand. A would have a higher incentive to produce more RES-E to sell it to B. Therefore, assuming reciprocity, consumers in B would be subsidising the import of TGCs from A into B.

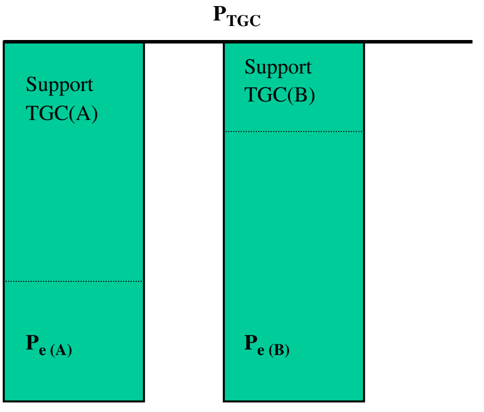

Fig. 8. National electricity market and international RES-E support policy.

Table 14
Summary of effects (sc. 2)

Electricity demand	= in both countries
TGC price	International market price
RES-E target	= in both countries (by assumption)
Price of electricity	Higher ↓ in A than in B
Specific RES-E support costs	Higher in A than in B
Consumer costs	?

This would distort the TGC market in A because consumers in A would be subsidising RES-E production in B.

If RES-E was supplied from B to A, a lower proportion of total demand in A would be supplied through conventional electricity. The international electricity price would remain unchanged, since it is set at international level. If A or B were large, accounting for a high proportion of total electricity demand, then they could affect the international electricity price. A higher RES-E generation could reduce this price and increase demand, but this would also depend on the increase in consumer costs as a result of RES-E support (Table 15).

**Scenario 4. International electricity market and international RES-E support policy*: If the two countries have different RES-E targets (ambitious in A and less stringent in B), then, since there is a unique international TGC price and electricity price, A would (ceteris paribus) end up buying TGCs to B.

Therefore, consumers in A would experience a larger reduction in the electricity price but would also face higher specific support costs. Thus, the comparative effect on consumers in both countries would be ambiguous. The consumers in A would be partly financing their more ambitious RES-E target with TGC imports (i.e., partly by funding RES-E deployment abroad).

Electricity demand would remain constant, but a higher proportion of total demand would be met with RES-E in A than in B. If A was large and B small, this would push

Table 15
Summary of effects (sc. 3)

Electricity demand	Unchanged
Price of electricity	= in both countries (↓ if A or B are large)
RES-E targets	More ambitious in A
P_{TGC}	$P_{TGC(A)} > P_{TGC(B)}$
RES-E deployment	Higher in A
Cost to consumers	Higher for A consumers

Table 16
Summary of effects (sc. 4)

Electricity demand		Price of electricity		Specific RES-E support costs		Consumer costs	
A	B	A	B	A	B	A	B
=	=	↓	↓	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)

down the international electricity price.[11] This may increase electricity demand in the following years but, again, the costs increase as a result of the RES-E policy should also be considered (Table 16).

To sum up, in general, RES-E promotion leads to a reduction of electricity prices, which is more pronounced in a national market than in an international market. The costs may be distributed differently between countries when a national or an international electricity market and a TGC scheme are considered. The following table summarises the effects in all the scenarios (Table 17).

Other aspects concerning RES-E promotion may affect electricity demand and consumer costs:

**Stringency of RES-E targets*: In our basic scenario a more ambitious RES-E target would reduce conventional electricity demand and would reduce the electricity price, leading to a higher electricity demand. However, if the higher costs of RES-E promotion are passed to the consumer, then it is unknown whether the increase in electricity demand will occur. A more stringent target in one country would involve a larger substitution of conventional electricity, a lower electricity price but, also, higher costs for its consumers. Therefore, the long-term effects on electricity demand of a higher RES-E support are unclear if the costs of the support policy fall on the electricity consumer. If they fall on the general taxpayer, then a higher electricity demand could be expected.[12]

**Already exploited RES-E potentials*: In countries which have already used a substantial proportion of their RES-E potential, a similarly stringent target would cause a

[11] i.e., the larger the country with the most ambitious RES-E target, the more likely the international electricity price will go down.

[12] As stressed by Huber et al (2004, p.29), "consumers in MS with a relative small quota, will enjoy the benefit of the international power and TGC price and only experience low extra costs of buying TGCs. Consumers in MS with a relative ambitious target, will also enjoy decreasing power and TGC prices too, but will have a larger share of the TGC price included in the consumer price".

Table 17
Summary of effects (all scenarios)

	Electricity demand		Price of electricity		Specific RES-E support costs		Costs for consumers	
	A	B	A	B	A	B	A	B
Scenario 1	?	=	↓	=	↑	=	?	=
Scenario 2	=[a]	=[a]	↓[b]	↓[b]	↑[c]	↑[c]	?	?
Scenario 3	=[a]	=[a]	↓[d]	↓[d]	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)
Scenario 4	=	=	↓	↓	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)

[a]Depending on the elasticity of demand.
[b]Higher reduction in B.
[c]Higher increase in A.
[d]Reduction if A and B are large.

comparatively higher cost for the consumer without affecting the electricity price. Electricity demand would tend to be lower than if a large RES-E potential is still available.

**Type of RES-E support scheme*: Primary instruments for RES-E promotion (feed-in tariffs, TGCs and tenders) are paid by the consumer, while "secondary instruments" (investment subsidies, fiscal and financial incentives) are financed through the general budget (paid by taxpayers). All of them contribute to RES-E support at the expense of conventional electricity and, therefore, they all reduce the electricity price. However, because of the way they are financed, the "primary instruments" would increase electricity consumer costs while "secondary" instruments would not (Fig. 9). Secondary instruments can thus be expected to provide a more intense incentive to increase electricity demand, while in the case of "primary instruments" this depends on the intensity of the two opposite effects. If the price reduction is larger than the increase in consumer costs, then an increase in electricity demand can be expected. It should also be noted that, since the impact of "secondary impacts" on RES-E promotion is smaller, their capacity to increase RES-E deployment is also limited).[13]

**Level of prices and structure of national electricity markets*: The response of electricity prices to changes in demand and supply largely depends on the competitive conditions (structure) of the national electricity markets. A more monopolistic-oligopolistic structure would lead to a lower response than a more competitive market. This issue is important because if this price does not change in response to variations in the marginal conditions at the conventional electricity market, then it is unlikely to lead to changes in electricity demand.[14]

[13]Some instruments may have more impact on consumer costs than others. In one specific RES-E support instrument increased consumer costs more than others, then this instrument would lead to a lower increase in electricity demand. Since a RES-E quota with TGCs is a quantity-based instrument, it is easier to predict what will be the future RES-E deployment in the future than if price-based instruments were used (such as feed-in tariffs). Therefore, it would also be easier to predict the amount of conventional electricity that will be needed to meet total electricity demand and, thus, the price of electricity at the spot market.

[14]On the other hand, it can be expected that when electricity prices are already low, the possibility that they go down would be lower then when they are high.

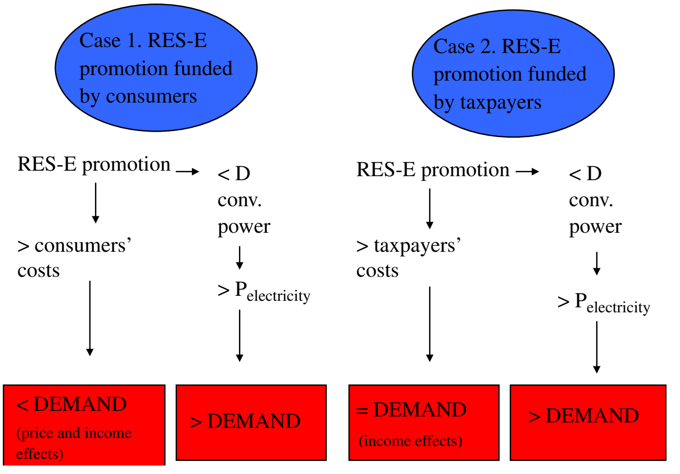

Fig. 9. Different impacts of "primary" and "secondary" instruments.

3.3. *Impact of CO_2 quotas and emission trading schemes (ETS) on electricity demand and consumer costs*

The implementation of a CO_2 quota and an ETS increases electricity prices. The producer must now control its emissions (abatement costs) and/or buy TEAs in the market. The sum of abatement costs and TEA purchases raises generation costs, shifting the electricity supply curve upwards and to the left and reducing the quantity being demanded. The more ambitious the CO_2 quota, the higher the cost of reduction and the higher the TEA price, the higher will the supply curve shift upwards and the larger the reduction in the electricity quantity being demanded.[15] The increase in the electricity price will depend on the price elasticity of demand and on other factors.

We can also distinguish four cases:

**Scenario 1. National electricity market and national climate change policy*: This is the basic case already described (Fig. 10).

The extent to which the higher cost translates into higher prices for electricity (cost pass-through) determines the share of the total burden that falls on electricity consumers in the country and depends on the price-setting behaviour within the electricity market, competitive pressure, price elasticity of the demand, market concentration and allocation method ([5]). The increase in the price for the final consumer could be above, similar or below the increase in generation costs (electric companies would partly absorb the increase in costs). Electricity consumers would be supporting the CO_2 reduction. If other countries do not implement a CO_2 quota, they would be free-riding on the efforts of A. The energy intensive industry in A would lose competitiveness and negative macroeconomic effects

[15]The extent to which the electricity supply curve shifts upwards will also depend on the type of TEA allocation scheme being used. For instance, with an auction-based allocation the curve would shift higher up than with a grandfathering (free allocation) scheme. In contrast, the use of the Kyoto Flexible Mechanisms would mitigate the impact of CO_2 quotas on the electricity supply curve and, therefore, a more modest shift of this curve could be expected.

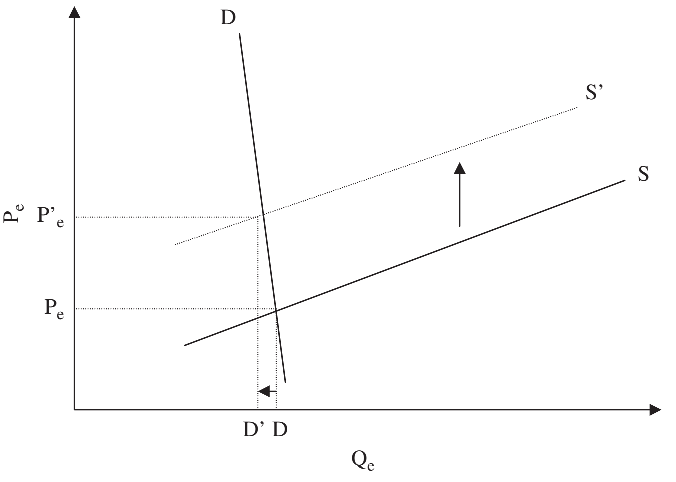

Fig. 10. National electricity market and national climate change policy.

would result (increase in the current account deficit, CPI and unemployment rate) (Table 18).

**Scenario 2. National electricity market and international climate change policy*: This is the situation in Europe from January 1st onwards, after the start of the EU ETS. Since the electricity liberalisation process is moving forward but at a slow pace, there will still be fragmented electricity markets in Europe by then.

A single TEA price would result, but there would be different electricity prices in the national markets. The impact of the CO_2 restriction on electricity firms in different MS would depend on many factors: their generation mix, the allowances provided by the NAPs, the evolution of electricity demand etc…

Thus, MS and firms in different MS will be affected differently by the EU ETS. Let's assume two MS, one (A) with a more ambitious CO_2 target for the electricity sector and/or higher abatement costs than B. Those countries with a comparatively clean generation mix but stringent targets would face comparatively more costs and further emissions reductions would increase costs.

In this situation, A would face more costs than B (sum of abatement costs and purchase of TEAs). Assuming the same (high) level of costs pass-through for simplicity, the supply curve of A would shift further up and to the left. A would experience a larger reduction in the quantity of electricity demanded and a larger increase in the price of electricity. Since no electricity interconnections are assumed, the higher price would be paid by final consumers. Those in A cannot escape this situation by buying electricity to B. To sum up, consumers in A would face higher costs, whereas consumers in B would be less affected. Probably the country with the more stringent target (A) would be a net TEA importer and B a net exporter. This would benefit firms in B at the expense of firms and consumers in A (Fig. 11) (Table 19).

**Scenario 3. International electricity market and national climate change policy*: A single electricity market exists, integrating different countries which would have a national CO_2 ETS, with different targets and different abatement opportunities and costs. A would, again, have a more ambitious target and/or higher abatement costs.

Table 18
Summary of effects (sc. 1)

Electricity price	↑ in A; = in B
Electricity demand	↓ in A; = in B
Costs for the consumers	↑ in A; = in B
Macroeconomic effects	Negative effects for A. No effects for country B (better competitive situation versus A)

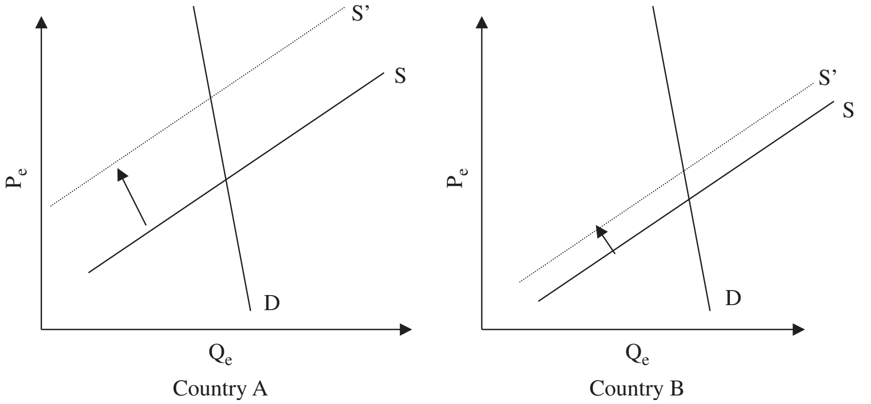

Fig. 11. National electricity market and international climate change policy.

Table 19
Summary of effects (sc. 2)

Electricity price	Increase in A > increase in B
Electricity demand	Reduction in A > reduction in B
Consumers costs	Much higher for consumers in A than for those in B
Macroeconomic effects	Negative effects on both countries, but more pervasive in country A

The electricity price is set by the interaction of the overall electricity demand and electricity supply. The supply curve would move upwards, given the increase in the overall costs of electricity generation due to the CO_2 restriction (Fig. 12). The international electricity price would rise and the quantity of electricity demanded would go down in both countries.

Compared to a situation without a common electricity market, the hypothetical supply curve in the high-cost country would have moved higher up than the overall supply curve (Fig. 13).

After the implementation of the EU ETS the price of electricity in the international market would be P_e. With national markets, the price in A would have risen to P'_A (above P_e) and to P'_B (below P_e). However, with an international market, electricity producers in A can only raise the price to P_e (if they rose the price by more consumers in A would buy electricity at the international electricity price in other countries). Consumers in A would

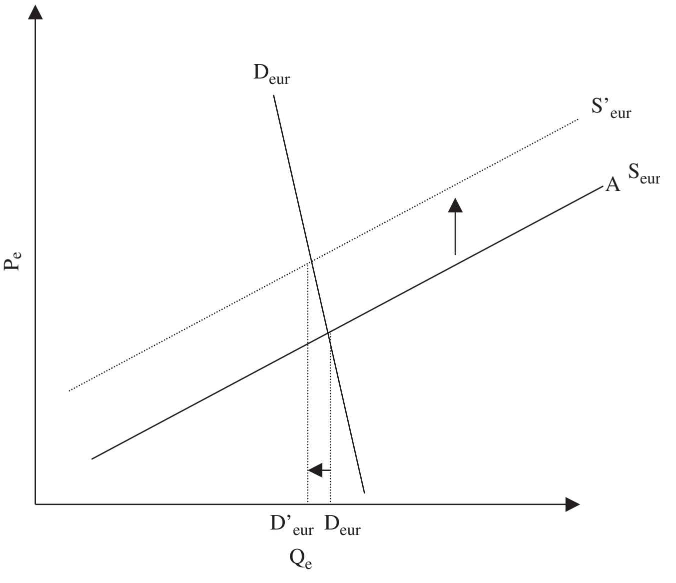

Fig. 12. International electricity market and national climate change policy.

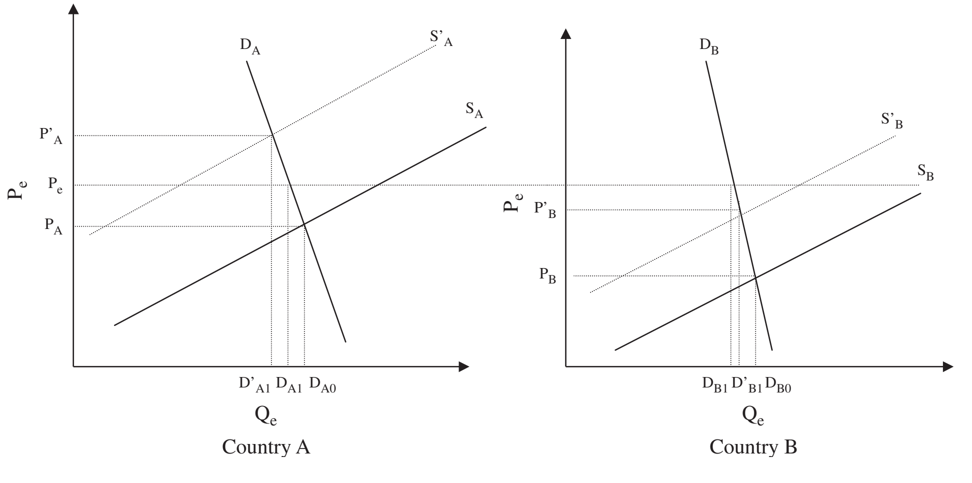

Fig. 13. National electricity markets and national climate change policy.

only absorb part of the cost increase as a result of the CO_2 restriction (the difference between the price they had to pay before, P_A, and the price they pay after, P_e) and electricity companies in A would absorb the rest (the difference between P'_A and P_e). This is in contrast to scenario 2, in which consumers in A absorbed all the costs. Consumers in B would only see their electricity price rise to P'_B if no international electricity market was in place. However, in an international electricity market, the price rises to P_e and their cost

Table 20
Summary of effects (sc. 3)

Electricity price (international)	↑
Electricity demand	↓ in both countries
Costs for the consumers	↑
Macroeconomic effects	Negative effects

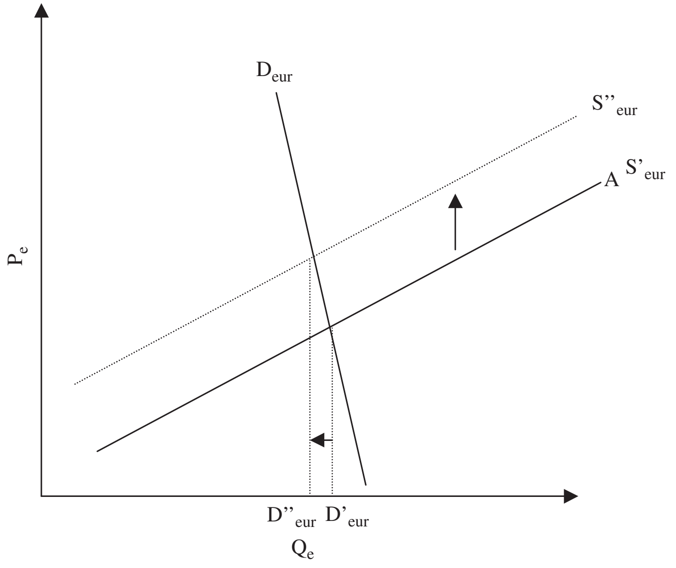

Fig. 14. International electricity market and international climate change policy.

increases by P'_B–P_e, more than it should. Consumers in B would be partly subsiding the CO_2 reductions in A through a lower electricity price in A.

The total quantity of electricity demanded in the international market would go down, since the price of electricity has increased. However, this is shared differently by countries. The electricity demand in A would decrease less (to D_{A1}) than without an international market (D'_{A1})[16] because the price of electricity has increased less in A (to P_e) than without an international market (P'_A). Exactly the opposite occurs in B, which experiences a greater demand reduction in an international electricity market (to D_{B1}) than in a national one (D'_{B1}) because the price increase is higher (P_e rather than P'_B).

To sum up, electricity demand reduction in A would be lower in an international electricity market than in a national market while the demand reduction in B would be higher in an international than in a national one (Table 20).

**Scenario 4. International electricity market and international climate change policy*: In this case, both the climate change policy and the electricity market would have an international character (full electricity interconnections). However, countries would still

[16]We have drawn a more elastic demand curve than before to show these differences.

have different costs of reaching their CO_2 target and the stringency of the CO_2 quota would also be different. As in the previous two scenarios, A has higher abatement costs/more stringent targets than the B (Fig. 14).

Following the introduction of an international ETS and CO_2 quota, electricity generation costs at the EU level would increase, shifting the supply curve upwards, increasing the electricity price and reducing the quantity being demanded. It can be expected that the electricity supply curve moves further up in scenario 3 than in scenario 4

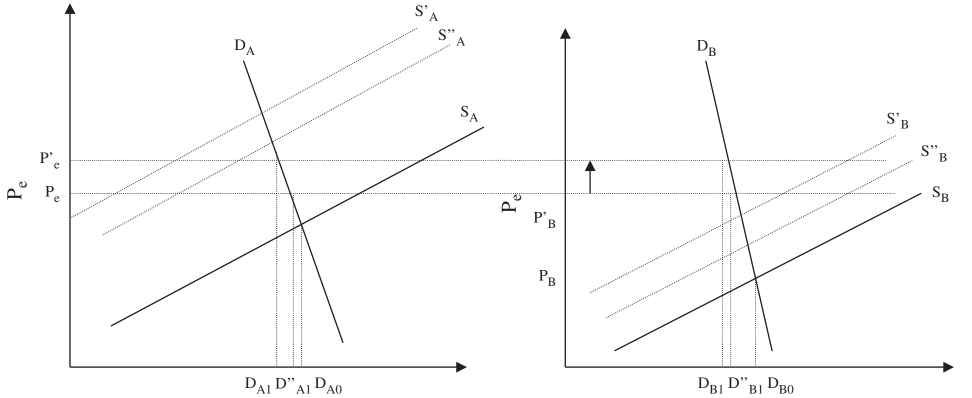

Fig. 15. Comparing scenarios 3 and 4.

Table 21
Summary of effects (sc. 4)

Electricity price	↑
Electricity demand	↓
Costs for the consumers	Much higher in A than in B
Macroeconomic effects	Negative effects on both countries (loss of competitiveness, higher current account deficit, CPI and unemployment rate), but more pervasive in A

Table 22
Summary of effects (all scenarios)

	Electricity price		Electricity demand		Costs for the consumers		Macroeconomic effects	
	A	B	A	B	A	B	A	B
Scenario 1	↑	=	↓	=	↑	=	(−)[a]	(+)[b]
Scenario 2	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)	↑(A) > ↑(B)	(−)[a]	(+)[b]
Scenario 3	↑	↑	↓	↓	↑	↑	(−)	(−)
Scenario 4	↑	↑	↓	↓	↑(A) > ↑(B)	↑(A) > ↑(B)	(−)	(−)

[a]Negative effects. Loss of competitiveness in international markets.
[b]Better competitive situation versus A (see text).

because an international CO_2 ETS is more cost-efficient in reaching national CO_2 quotas than non-integrated national CO_2 schemes. Thus, the rise in the international electricity price would be lower than in scenario 3 and the reduction in electricity demand would also be lower. In general, the same effects than in scenario 3 can be expected but at much lower levels. The costs for consumers and electricity companies in A would be lower. The costs for consumers would also be lower in B and firms in B could even be better off in absolute terms if they could sell TEAs. In Fig. 15 the results of scenario 3 and 4 are compared (Table 21).

Table 22 summarises all the cases considered in this section.

4. Limitations of the study and suggestions for further research

Only the most relevant variables, cases and scenarios have been considered in this paper. The main limitations of this study and some suggestions for further research are:

- The analysis could be extended to other relevant instruments (energy or carbon taxes, measures to promote CHP, etc…).
- The major effects considered are basically static. The inclusion of dynamic effects is important and should be analysed in the future.
- However, the assumption of "perfect competition" may not be very realistic when studying the electricity market and may affect the quantity of effects, although probably not their direction.
- Instruments do not really work in isolation but interact between each other in complex ways, possibly leading to synergistic as well as conflicting effects, affecting electricity demand and consumer costs.[17]
- The impact of instruments on electricity demand could be different in peak and base-load periods. If the elasticity of demand in both periods was different, then our analysis would have different implications in both periods. Furthermore, the likely effects of energy and environmental policies and measures on the elasticity of the demand curve should be analysed, and not only the shift in electricity demand curves.
- Only the direction of effects has been considered, but not their quantity. However, this is an issue to be analysed empirically.
- We assume that the variations of the cost faced by the generators are passed to the electricity price. This may be true when there is an increase in generation costs (i.e., the increase of generation costs is subsequently transmitted to the final electricity price) but that a certain rigidity to price reduction exists.
- We do not consider income effects as a result of the price reduction (i.e., a sort of "rebound effect"). We assume that the increase in consumer disposable income as a result of the reduction in the consumption of (non-service) electricity demand would not be spent on electricity consumption. Although, in general, these effects are expected to be small since electricity costs represent a relatively small share in the total expenditures of consumers (households), they could be significant in the case of electricity-intensive firms.

[17] Work on this topic has already been carried out. See [1,2] in this regard.

5. Concluding remarks

This paper has analysed the impact of energy efficiency and environmental goals and instruments on electricity demand and consumer costs under a wide variety of cases and scenarios.

Energy and environmental goals tend to reduce electricity demand, either directly by affecting the demand curve itself or indirectly by shifting the supply curve and, thus, changing the quantity demanded. The direction of these effects is relatively clear cut but its quantification is subject to the empirical investigation of specific situations. The impact of these policies on consumer costs is not so straight forward in most situations being analysed, since it depends on several factors such as the degree of cost-pass through (i.e., how the costs of the policy are charged to the final consumer if at all) and the elasticity of demand and supply curves. The impact also depends on the policy setting or scenario in which measures are applied (i.e., international or national markets for electricity and international or national character of the policies).

The paper shows that the effectiveness and impact of those measures largely depends on the demand response in the electricity market. An additional conclusion is that, when either the electricity markets or the support policies are national, distortions may occur, i.e. the reductions in electricity demand in one country may be subsidised by consumers or taxpayers in another country.

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